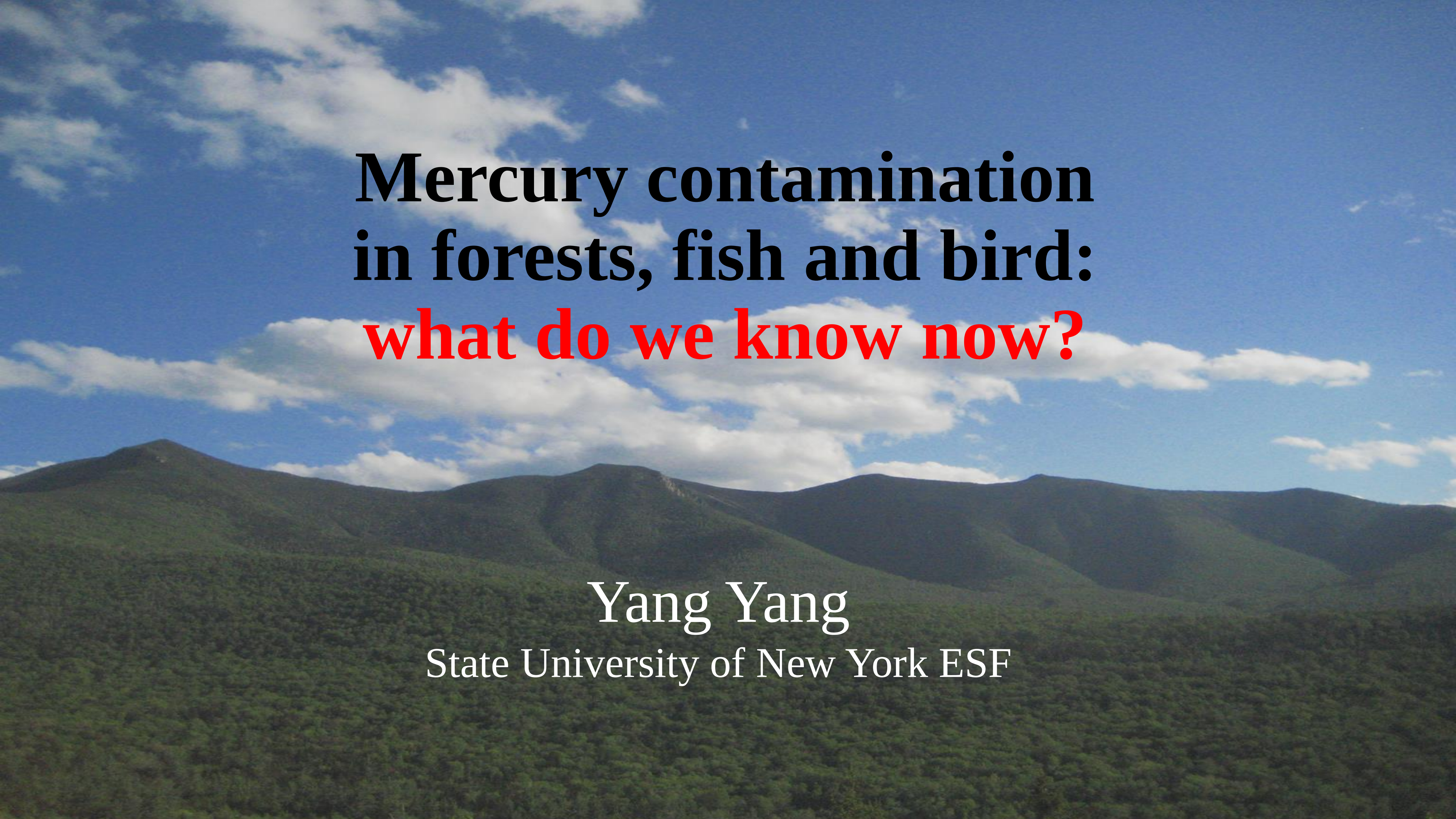
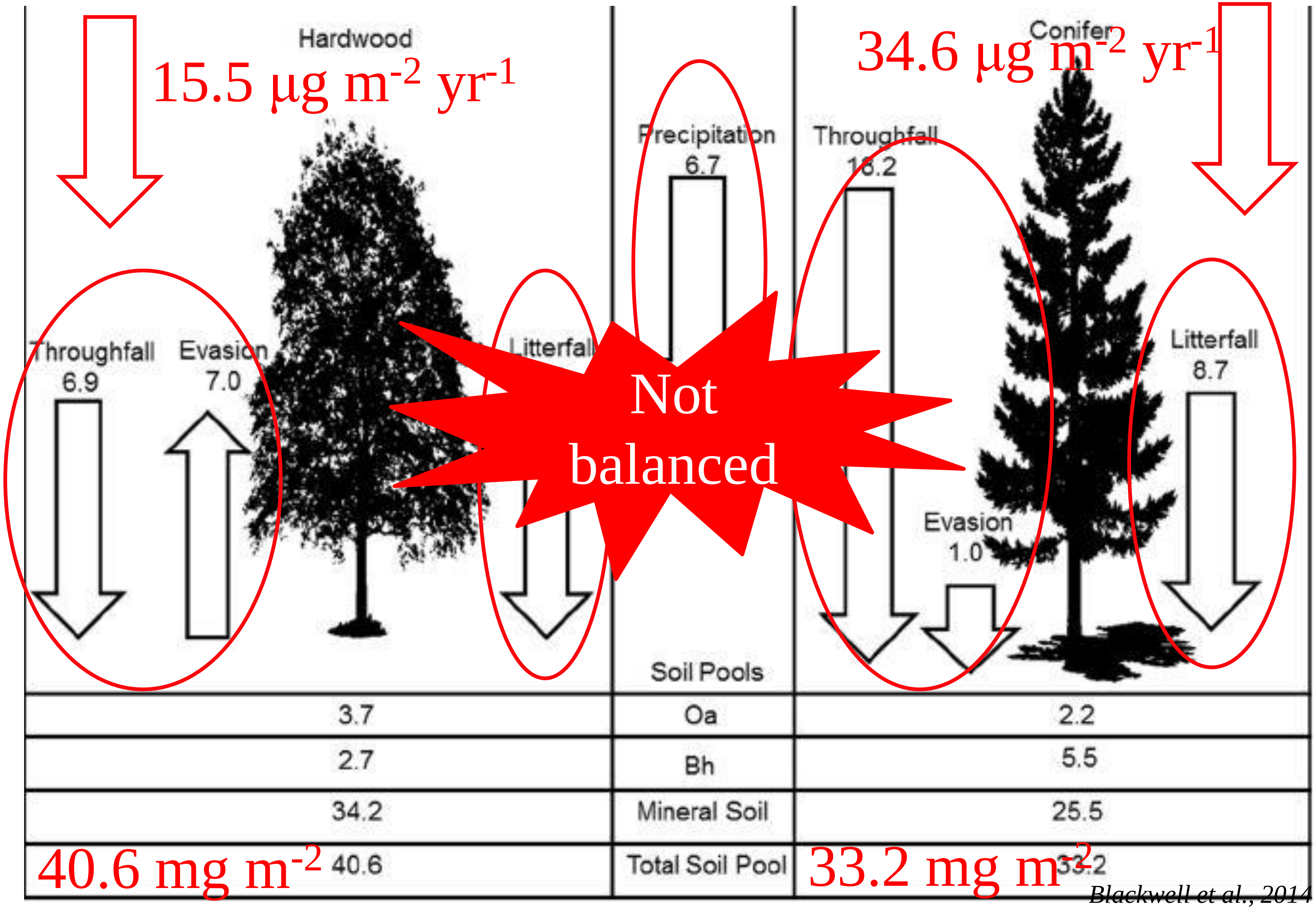


Mercury contamination in forests, fish and bird: what do we know now?

Yang Yang

State University of New York ESF

Can we construct a mercury budget in the forest?



15.5 μg m^{-2} yr^{-1}

34.6 μg m^{-2} yr^{-1}

Not balanced

	Soil Pools	
3.7	Oa	2.2
2.7	Bh	5.5
34.2	Mineral Soil	25.5
40.6	Total Soil Pool	33.2

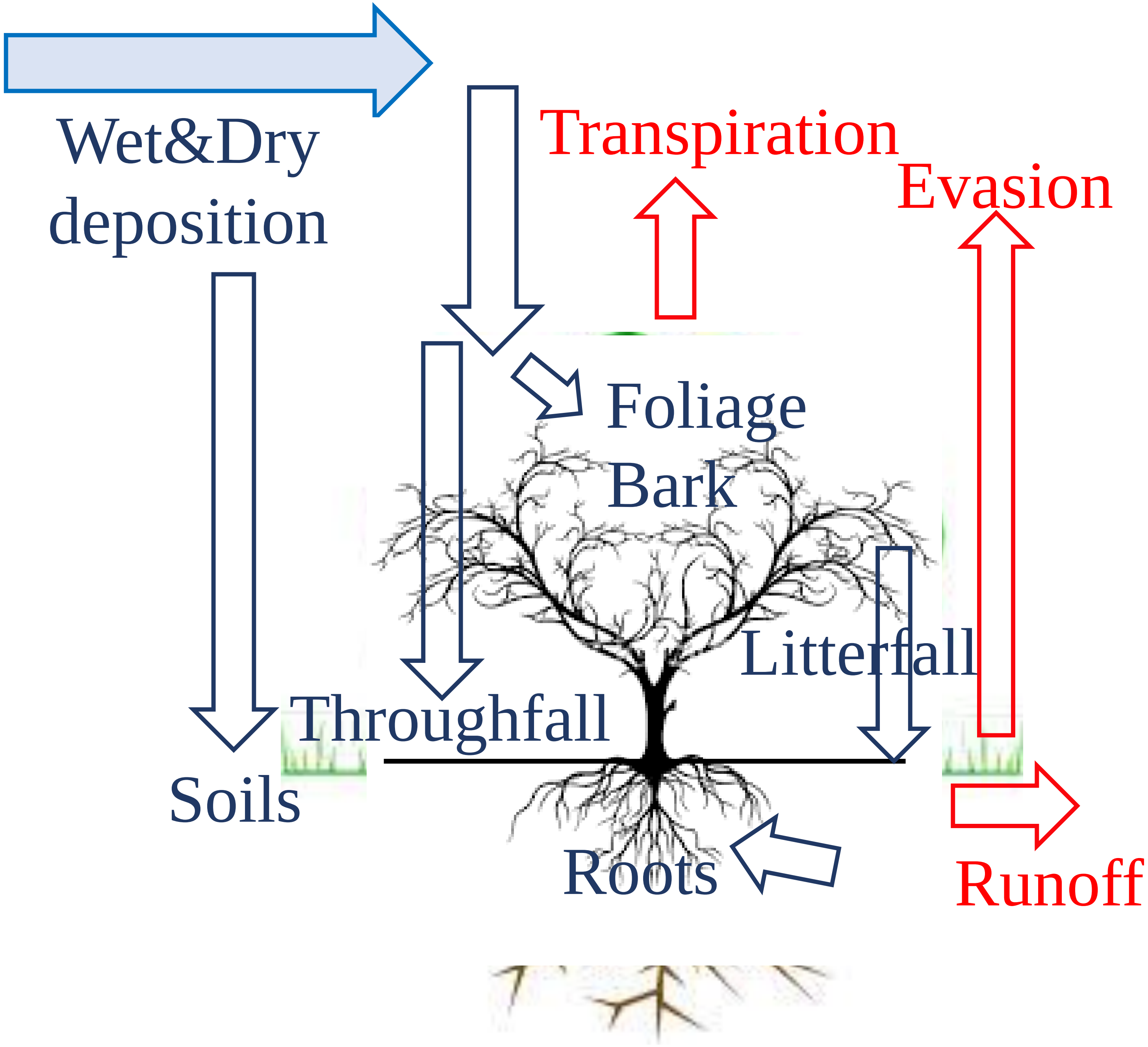
40.6 mg m^{-2}

33.2 mg m^{-2}

Blackwell et al., 2014

Sources

Elemental Hg
reactive gaseous Hg
particulate Hg



Wet&Dry deposition

Transpiration

Evasion

Foliage

Bark

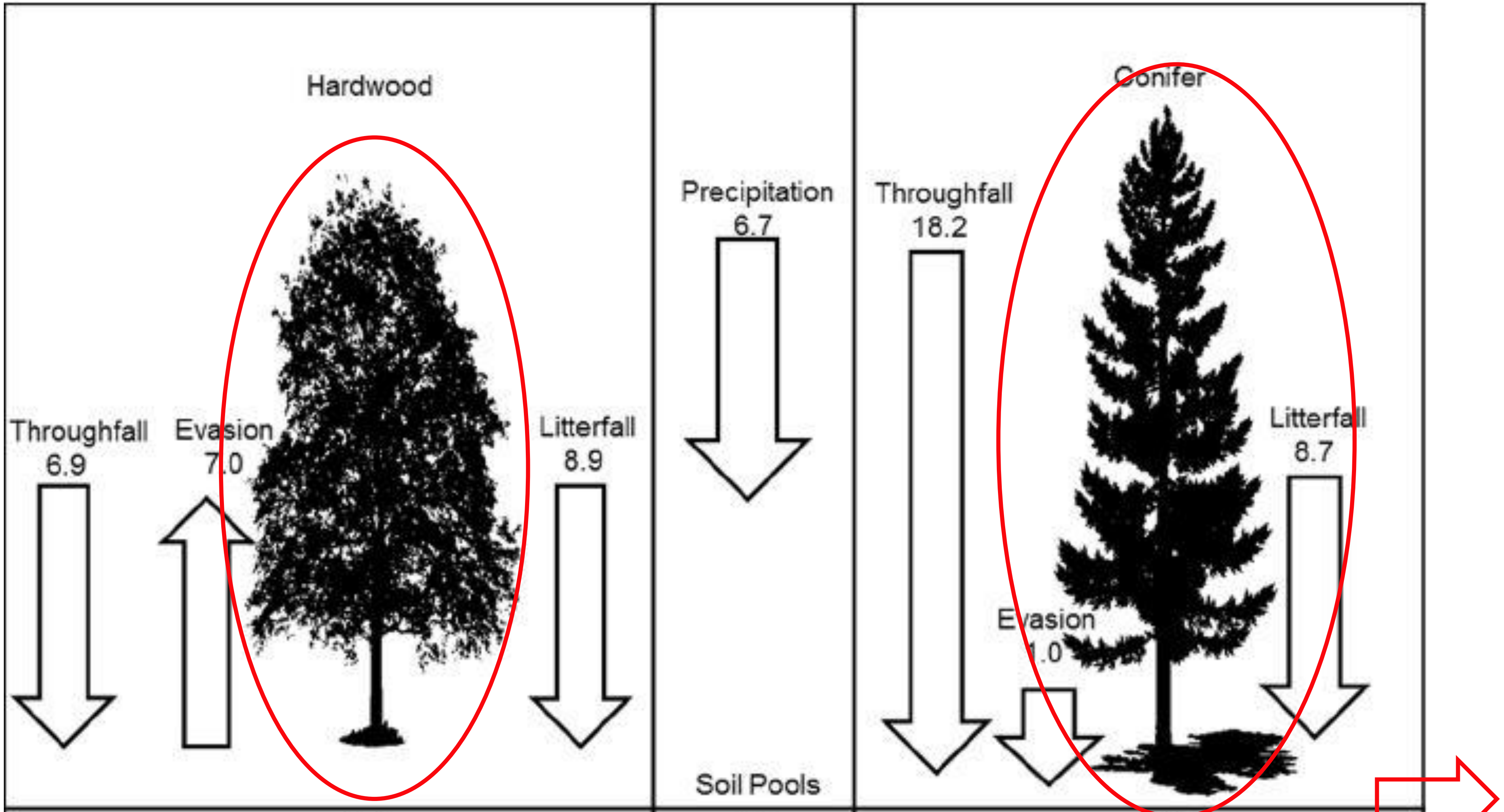
Litterfall

Throughfall

Soils

Roots

Runoff



	Soil Pools	
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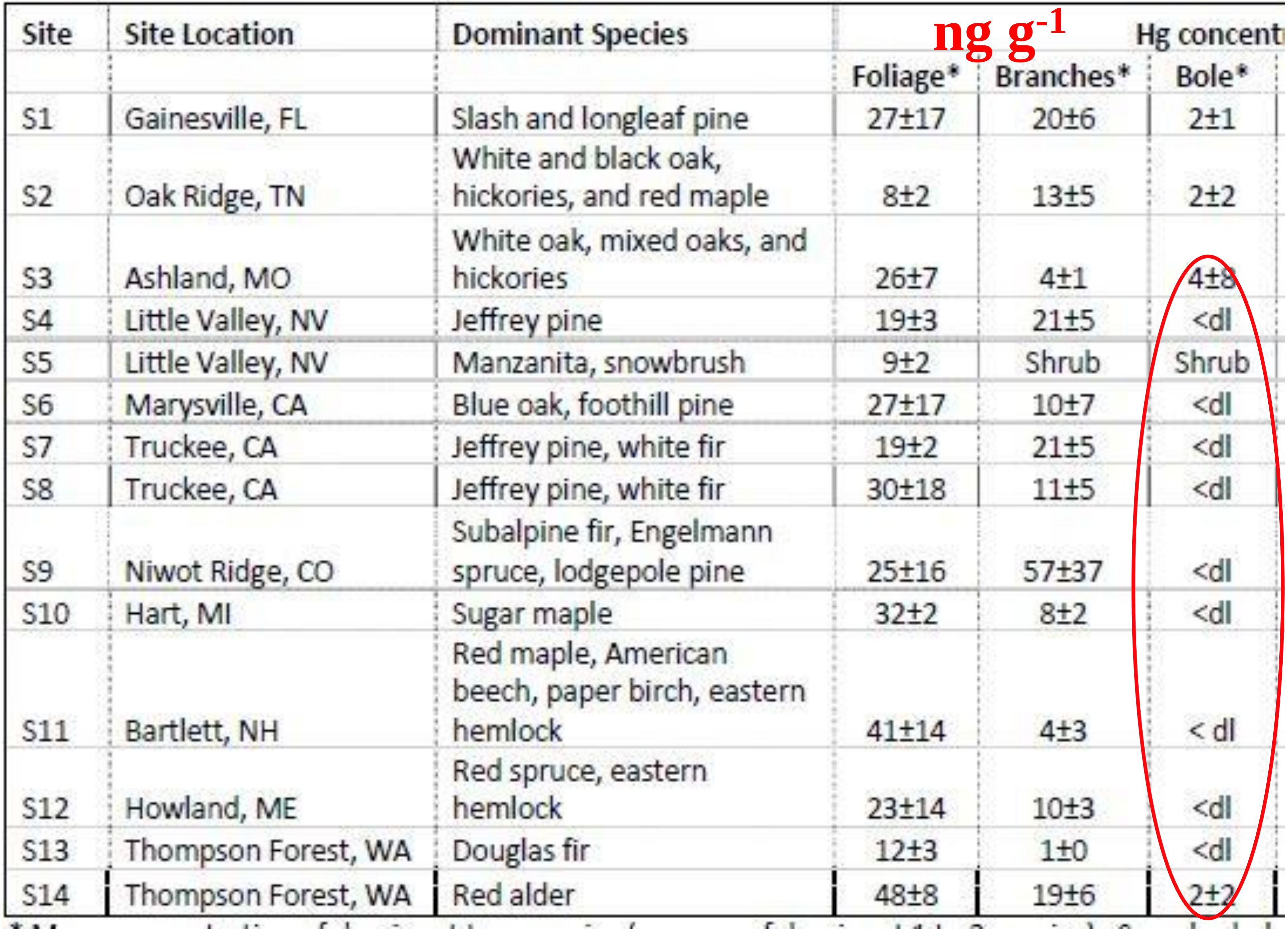
Blackwell et al., 2014



ng g^{-1}

Site	Site Location	Dominant Species		Hg concent	
			Foliage*	Branches*	Bole*
S1	Gainesville, FL	Slash and longleaf pine	27±17	20±6	2±1
S2	Oak Ridge, TN	White and black oak, hickories, and red maple	8±2	13±5	2±2
S3	Ashland, MO	White oak, mixed oaks, and hickories	26±7	4±1	4±8
S4	Little Valley, NV	Jeffrey pine	19±3	21±5	<dl
S5	Little Valley, NV	Manzanita, snowbrush	9±2	Shrub	Shrub
S6	Marysville, CA	Blue oak, foothill pine	27±17	10±7	<dl
S7	Truckee, CA	Jeffrey pine, white fir	19±2	21±5	<dl
S8	Truckee, CA	Jeffrey pine, white fir	30±18	11±5	<dl
S9	Niwot Ridge, CO	Subalpine fir, Engelmann spruce, lodgepole pine	25±16	57±37	<dl
S10	Hart, MI	Sugar maple	32±2	8±2	<dl
S11	Bartlett, NH	Red maple, American beech, paper birch, eastern hemlock	41±14	4±3	< dl
S12	Howland, ME	Red spruce, eastern hemlock	23±14	10±3	<dl
S13	Thompson Forest, WA	Douglas fir	12±3	1±0	<dl
S14	Thompson Forest, WA	Red alder	48±8	19±6	2±2

Obrist et al., 2011

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2014

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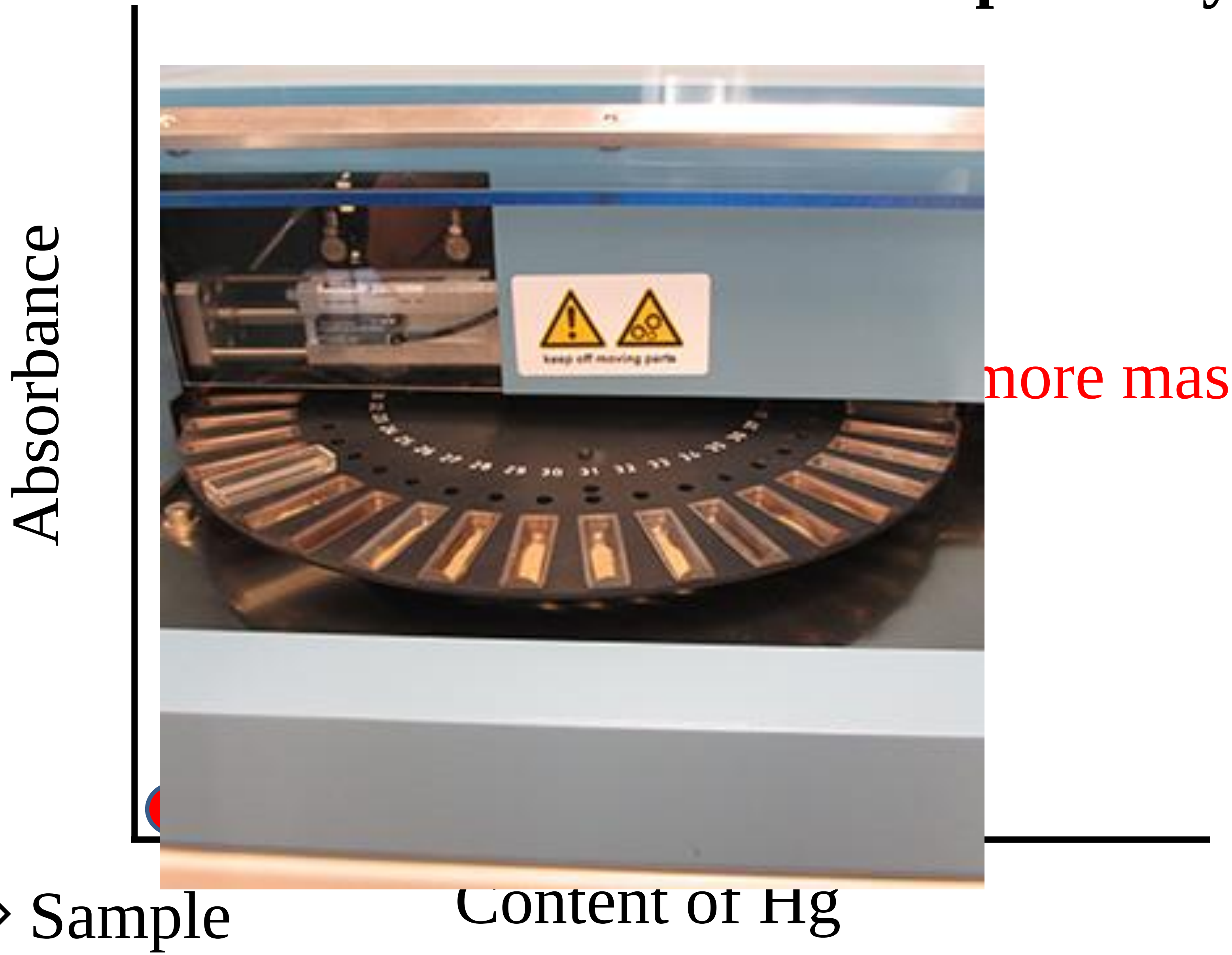
Testing if we can detect Hg in wood samples

Concentration of
Hg in wood = **1-2 ng g^{-1}**
or less

Analytical methods for analyzing mercury

	EPA method
A	1631E
IC p	6020A
N	7471B
a abs	7473
	3051A
IC	6010B

Sample analysis



nore mass!!

⇨ Sample

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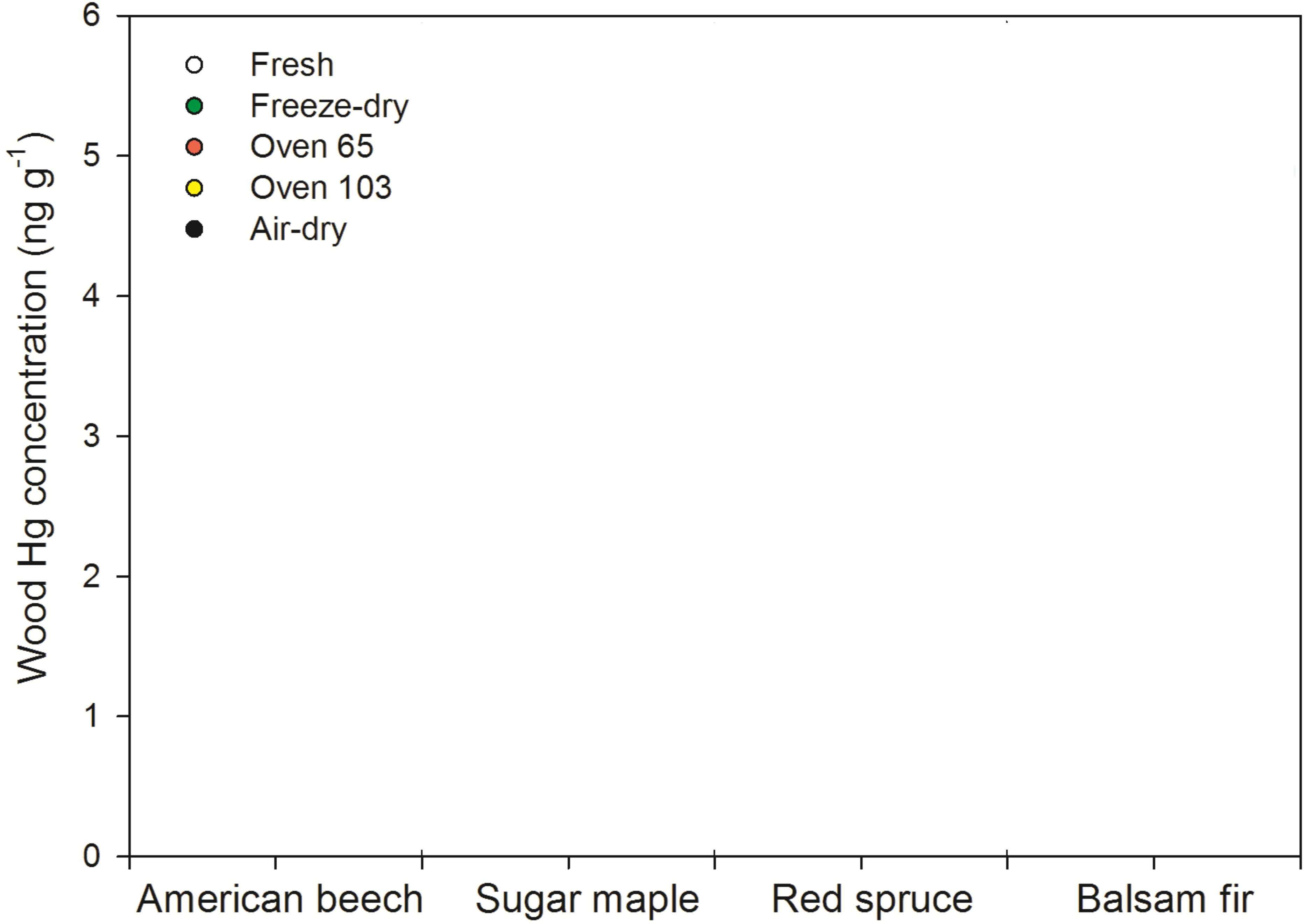
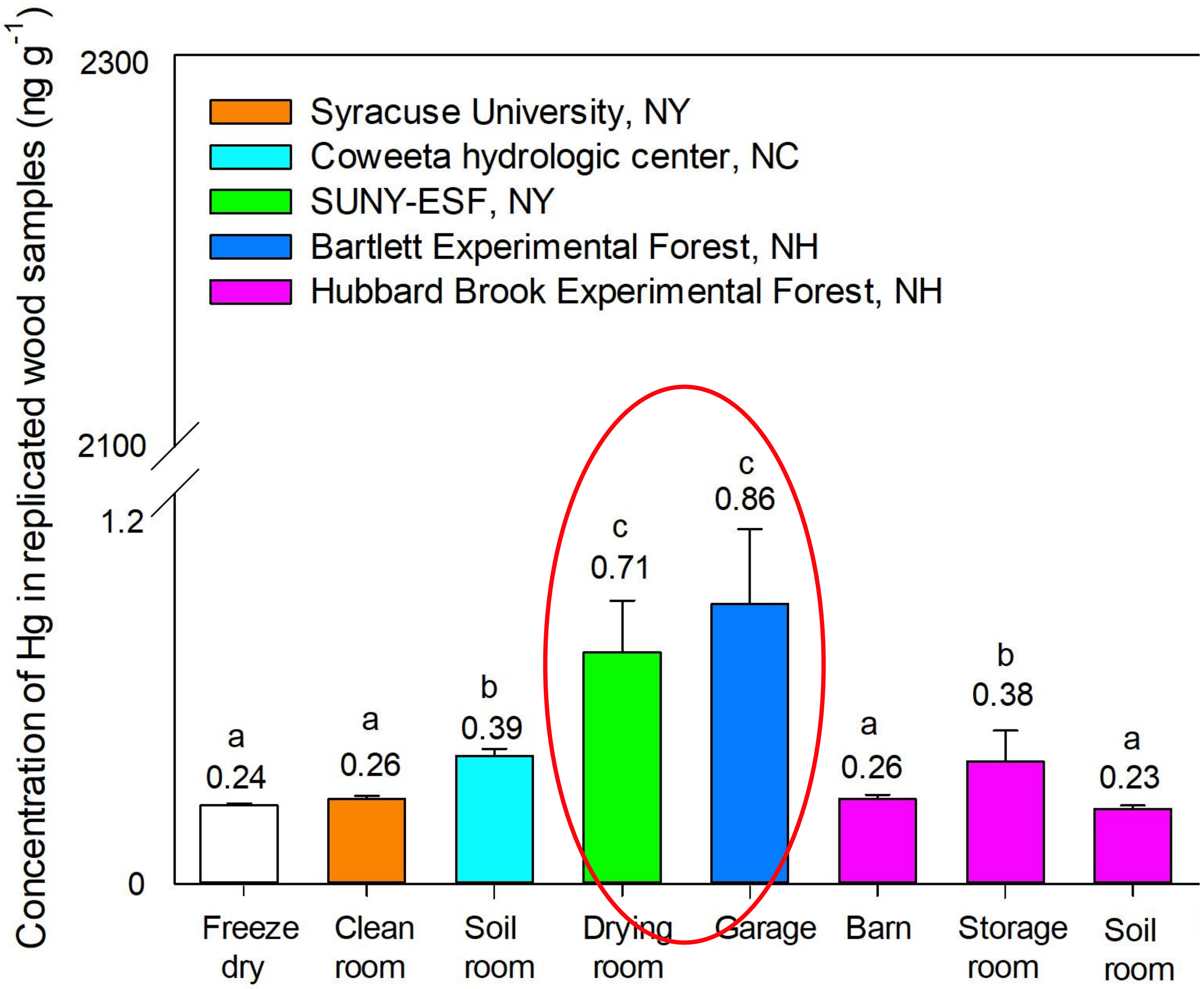
2014 2015

1. Develop an appropriate method to detect Hg in wood samples
2. Quantify concentrations and pools of Hg in trees



Fresh
Freeze-dry
Oven 65
Oven 103
Air-dry
Wood Hg concentration (ng g^{-1})
0
1
2
3
4
5
6
American beech
Sugar maple
Red spruce
Balsam fir


Concentration of Hg in replicated wood samples (ng g-1)
2300
2100
1.2
0
Syracuse University, NY
Coweeta hydrologic center, NC
SUNY-ESF, NY
Bartlett Experimental Forest, NH
Hubbard Brook Experimental Forest, NH
a
0.24
a
0.26
b
0.39
c
0.71
c
0.86
a
0.26
b
0.38
a
0.23
Freeze dry
Clean room
Soil room
Drying room
Garage
Barn
Storage room
Soil room


Hg
Mercury

Yang Yang, Ruth Yanai, Mario Montesdeoca, Charles Driscoll. 2017. Measuring mercury in wood: challenging but important. International Journal of Environmental Analytical Chemistry, 97(5), pp.456-467

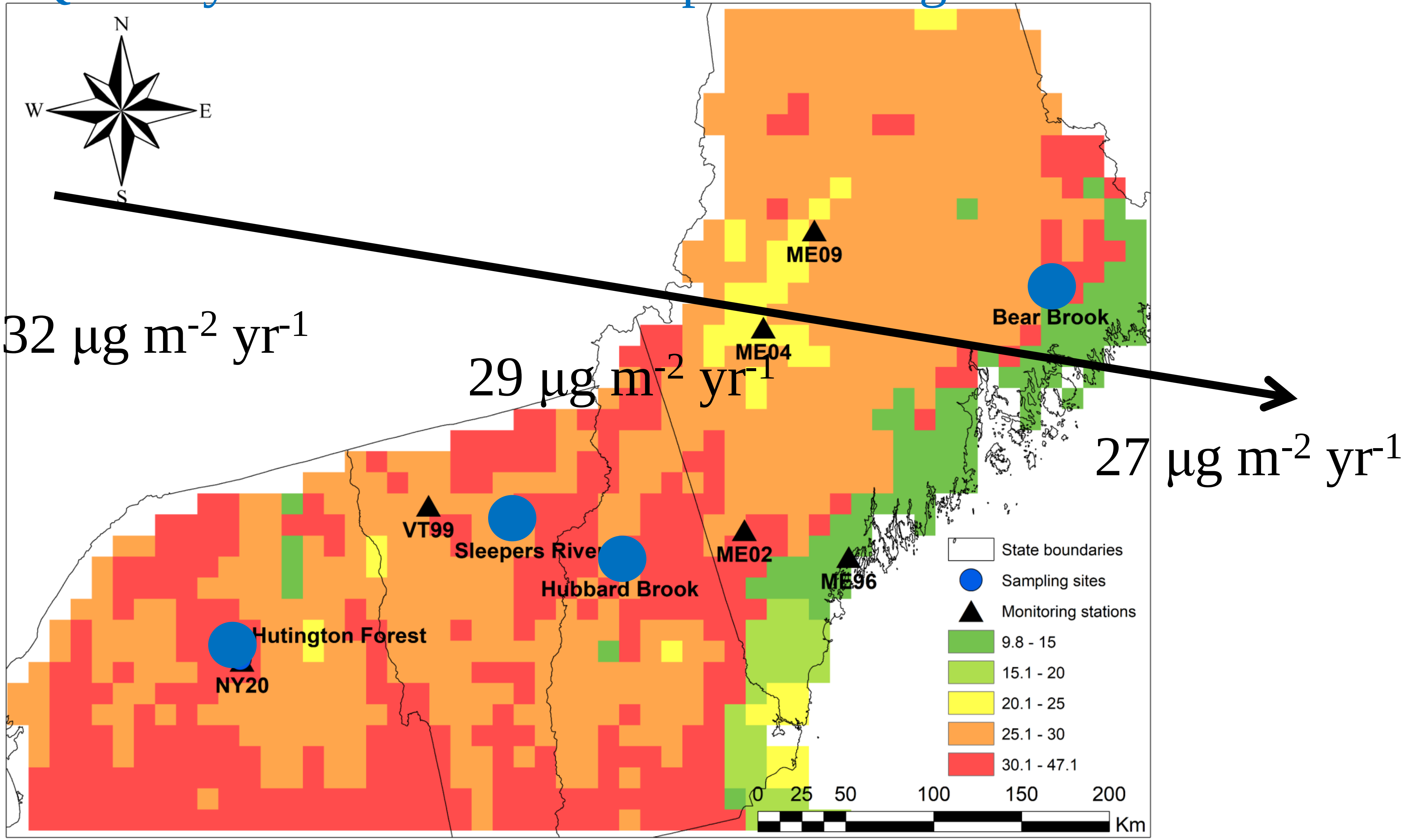
1. Freeze drying and oven-drying at 65 °C were appropriate

2. Oven-drying at 103 °C resulted in Hg losses

3. Air-dried samples should be analyzed with caution

4. Using a Milestone DMA 80 direct Hg analyzer can detect Hg in wood samples

Quantify concentrations and pools of Hg in trees



32 µg m^{-2} yr^{-1}

29 µg m^{-2} yr^{-1}

27 µg m^{-2} yr^{-1}

Sampling in the field

ood stands

ech, yellow birch,

C

n,

Red spruce,

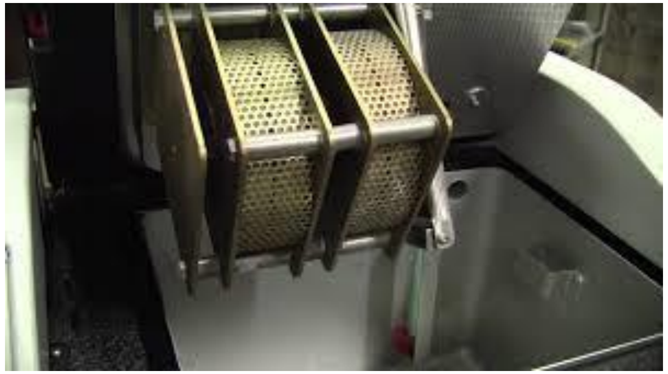
n,

4 American

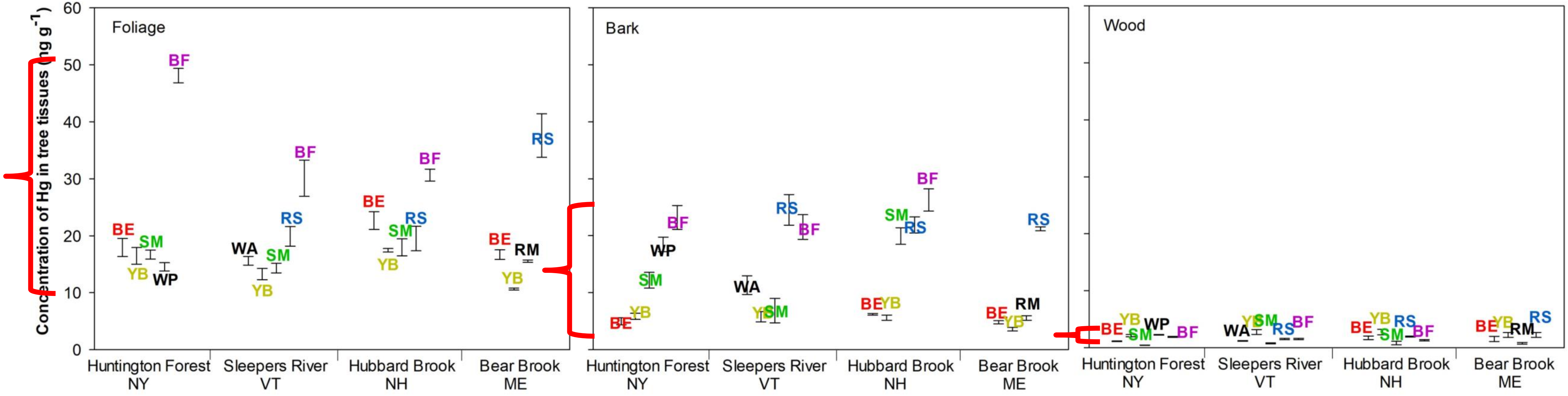
red maple

Processing in the laboratory

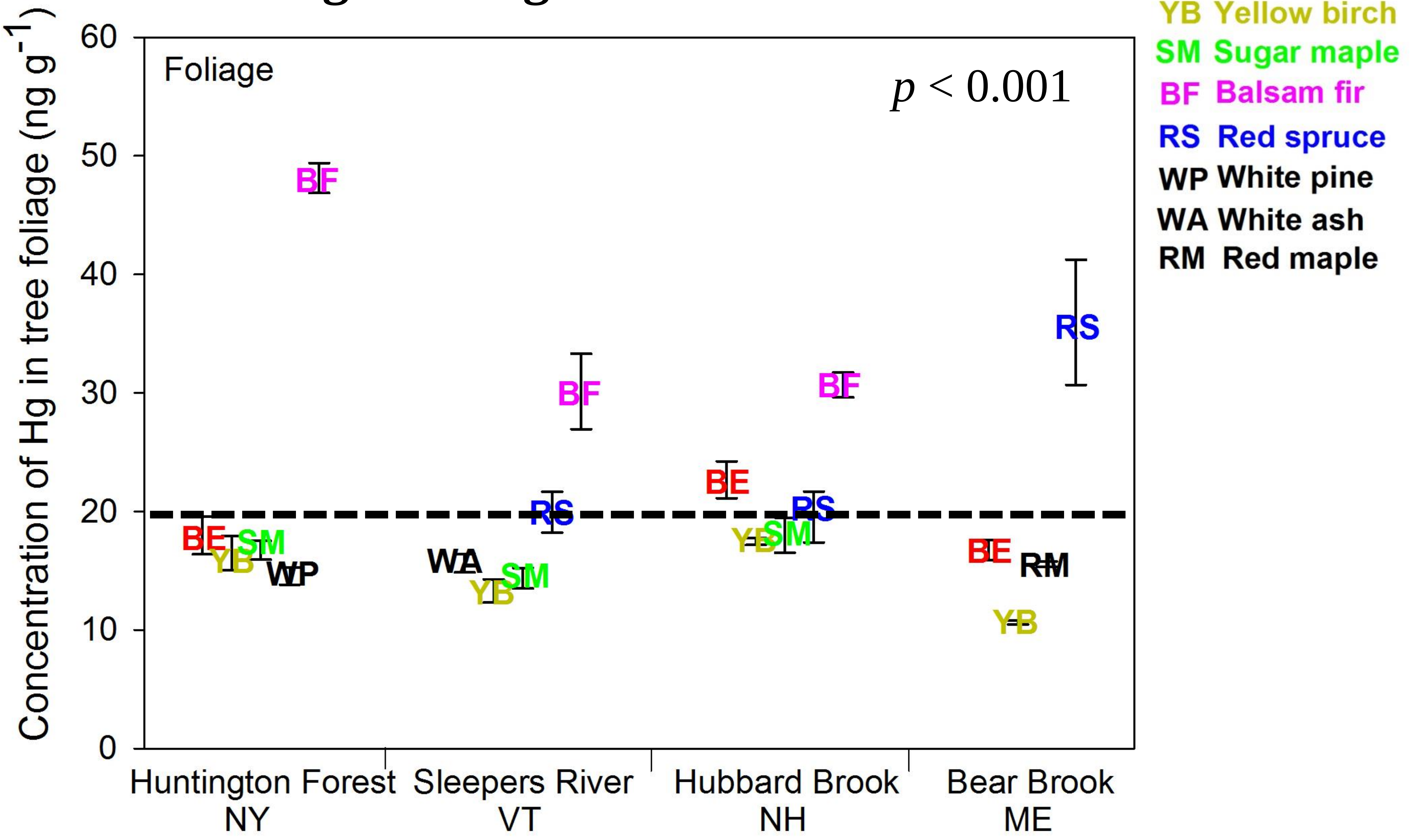
Clean samples



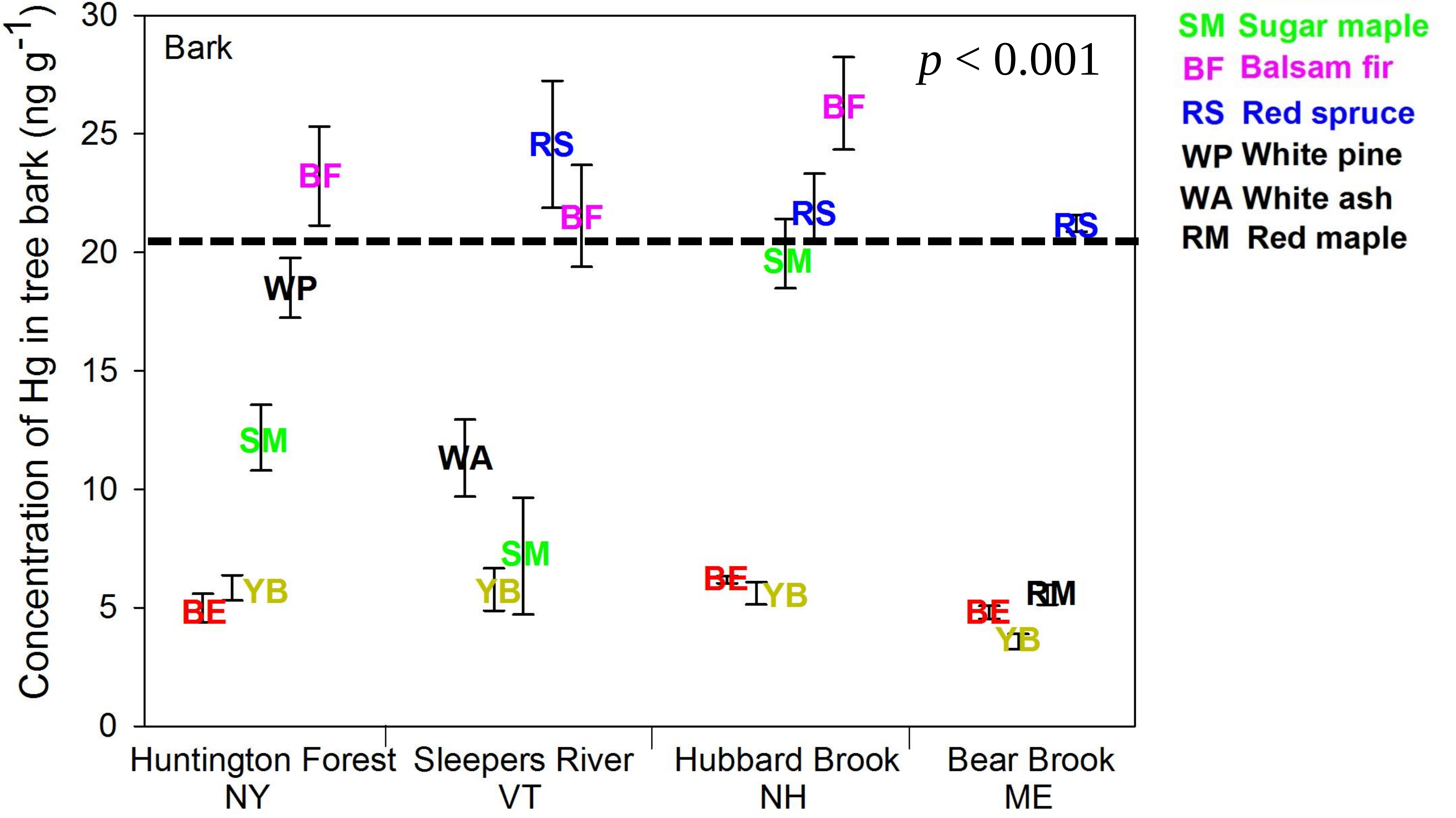
Concentrations of Hg in foliage, bark and wood



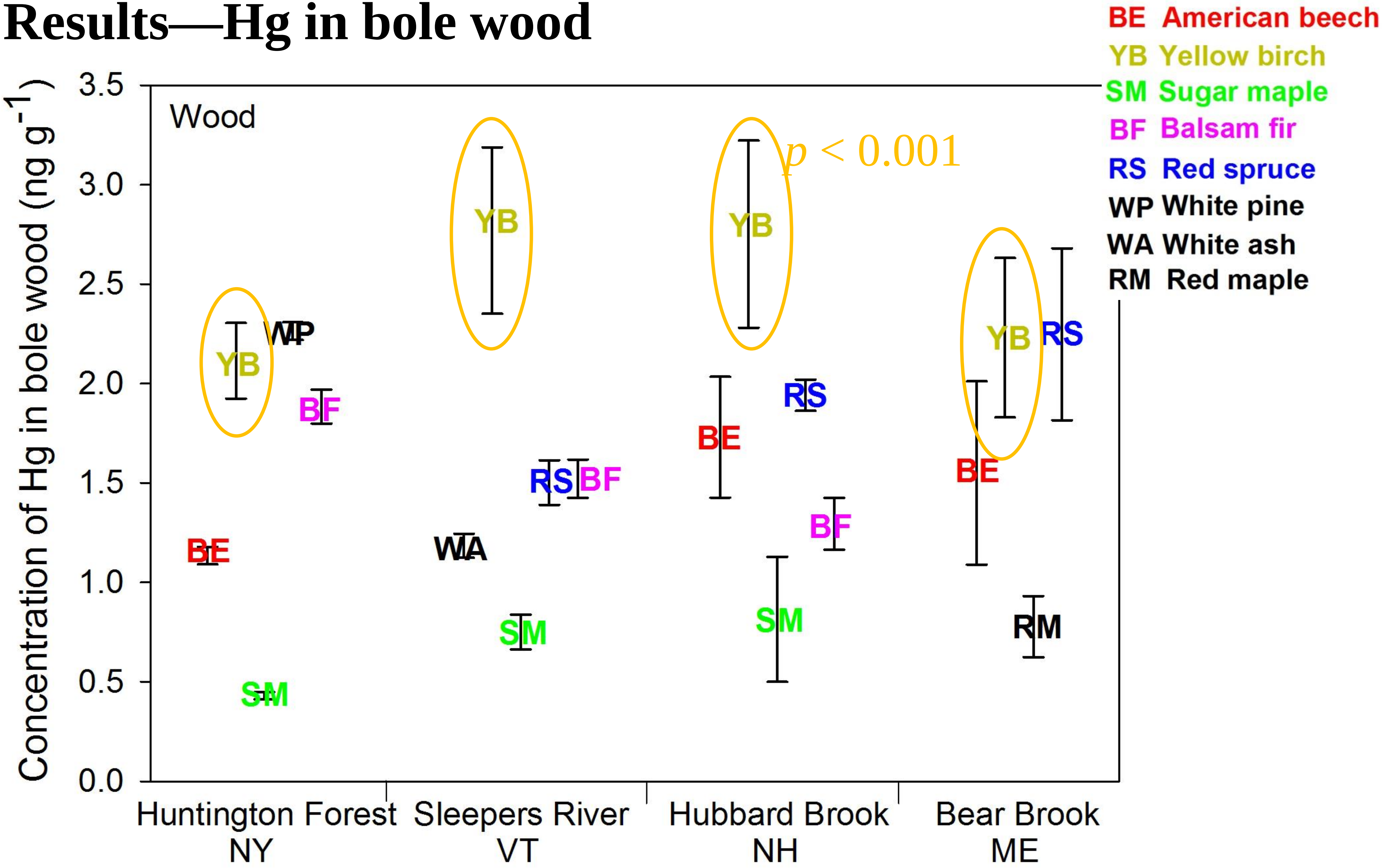
Results—Hg in foliage



Results—Hg in bole bark

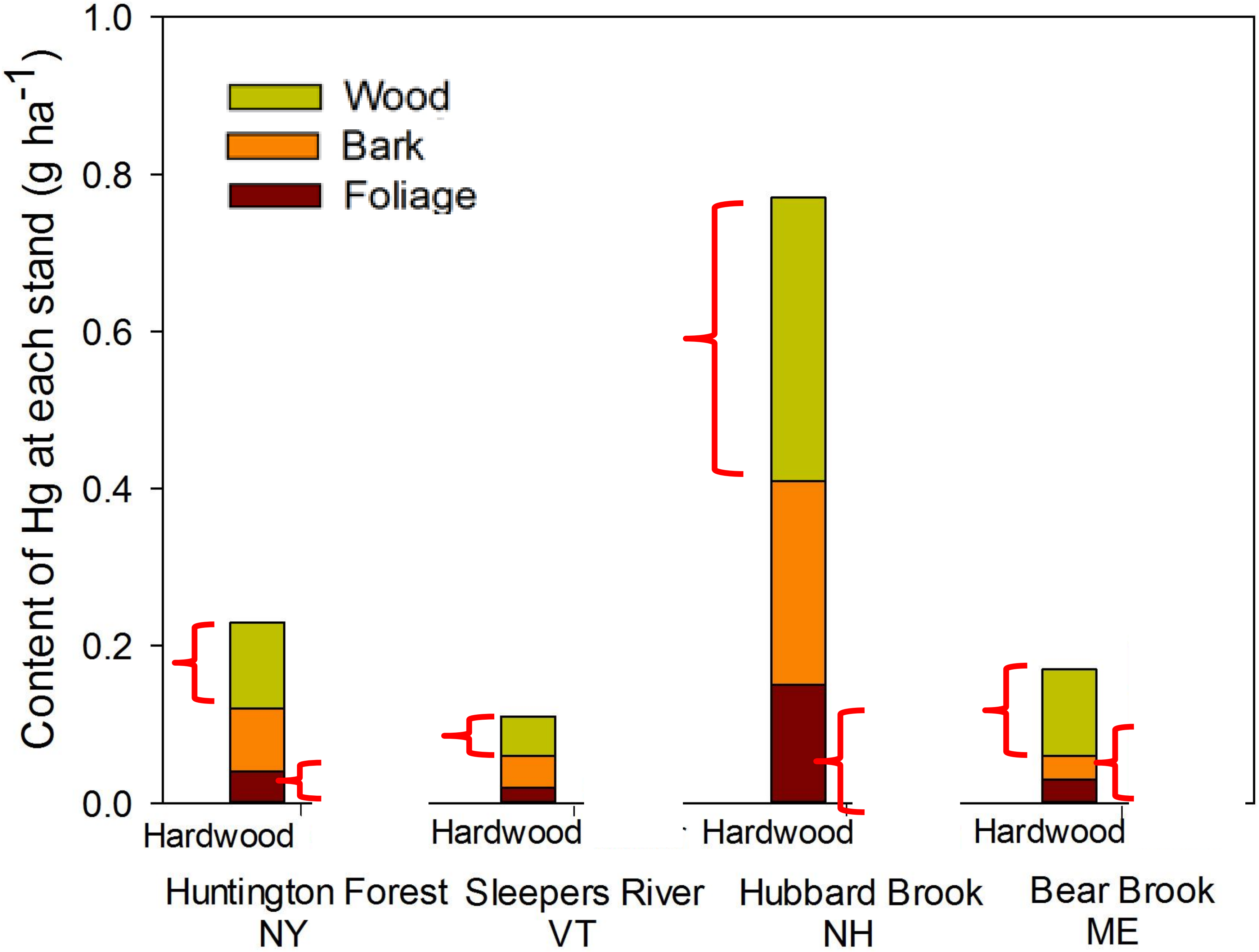


Results—Hg in bole wood



$p < 0.001$

Results—Content of Hg



Yang Yang, Ruth Yanai, Charles Driscoll, Mario Montesdeoca and Kevin Smith. 2018. Concentrations and content of mercury in bark, wood, and leaves in hardwoods and conifers in four forested sites in the northeastern USA. PLoS ONE. 13(4): e0196293.

1. Conifers usually had higher Hg concentration than hardwood species in bark and foliage but not in wood

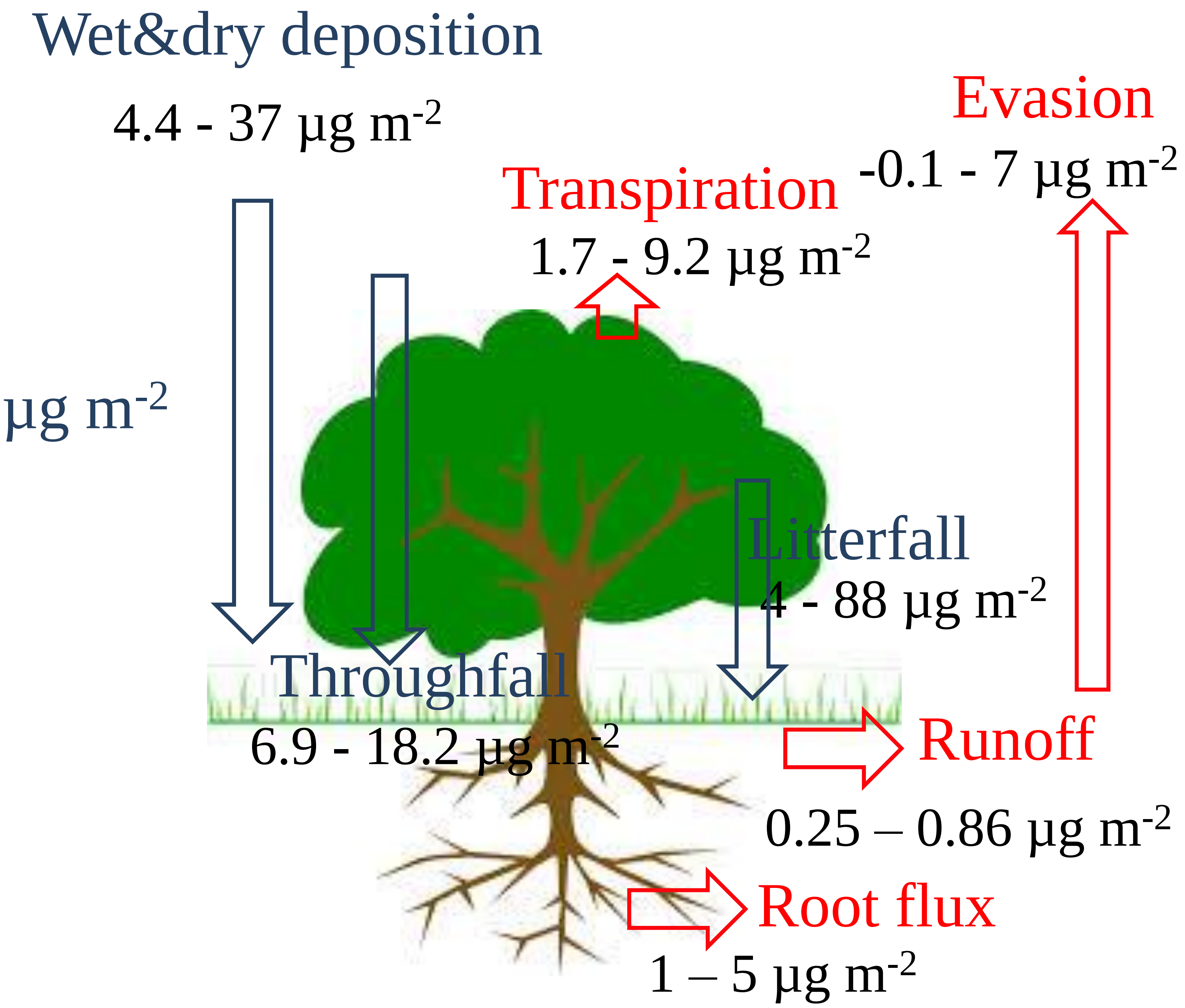
2. Aboveground Hg pools cannot explain the missing pool in conifer stands compared to hardwood stands

3. Wood is important!!

Bark and bole wood contained more Hg than foliage

Always true in hardwood stands but not in conifer stands

Soils	9,000-22,000 µg m^{-2}
Branches	1-69 µg m^{-2}
Wood	1-54 µg m^{-2}
Foliage	1-43 µg m^{-2}
Bark	1-33 µg m^{-2}



Wet&dry deposition

4.4 - 37 µg m^{-2}

Evasion

-0.1 - 7 µg m^{-2}

Transpiration

1.7 - 9.2 µg m^{-2}

Litterfall

4 - 88 µg m^{-2}

Throughfall

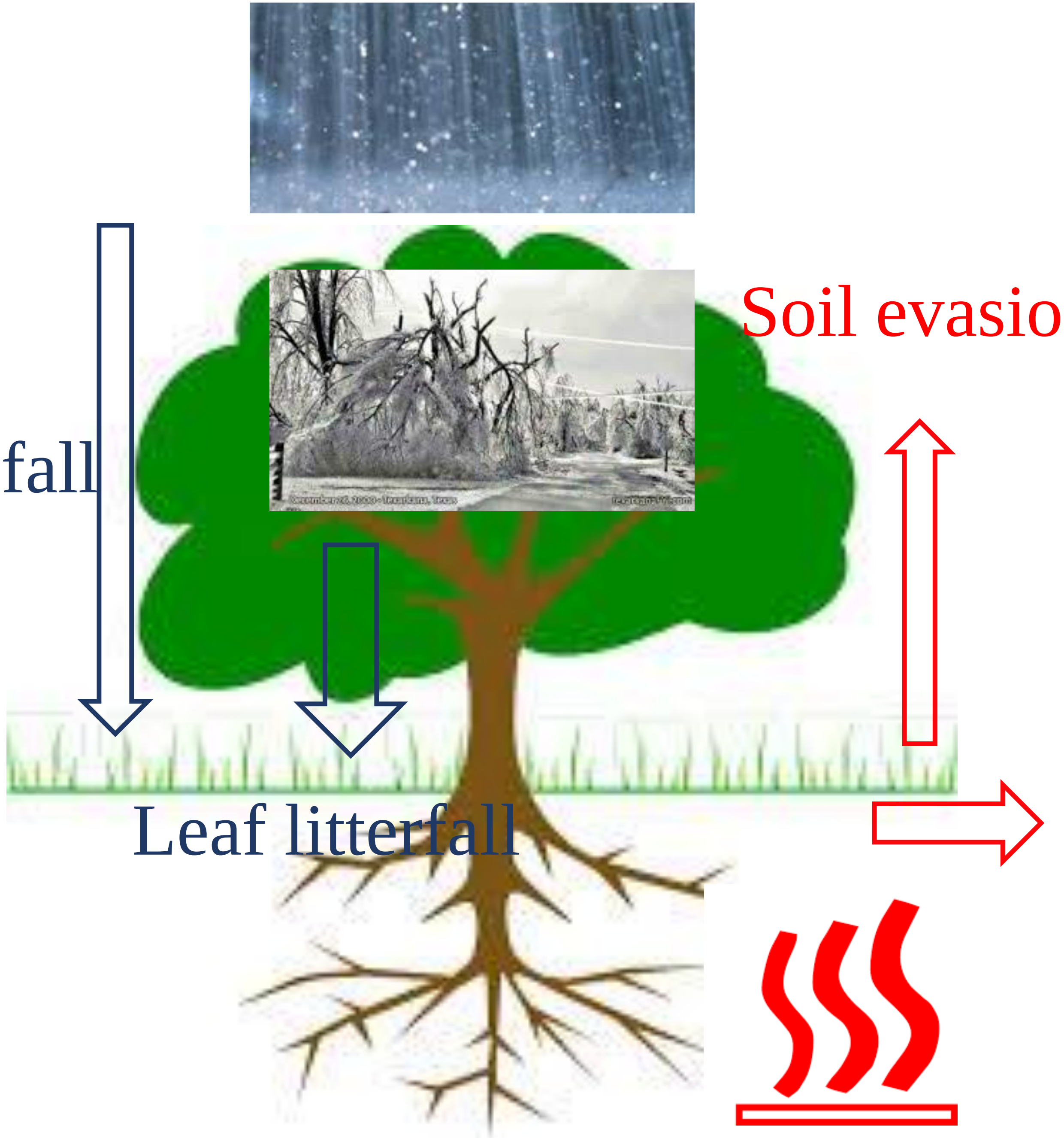
6.9 - 18.2 µg m^{-2}

Runoff

0.25 – 0.86 µg m^{-2}

Root flux

1 – 5 µg m^{-2}



Throughfall

Soil evasion

Leaf litterfall

Soil solution

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Edna Bailey
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BOSTON
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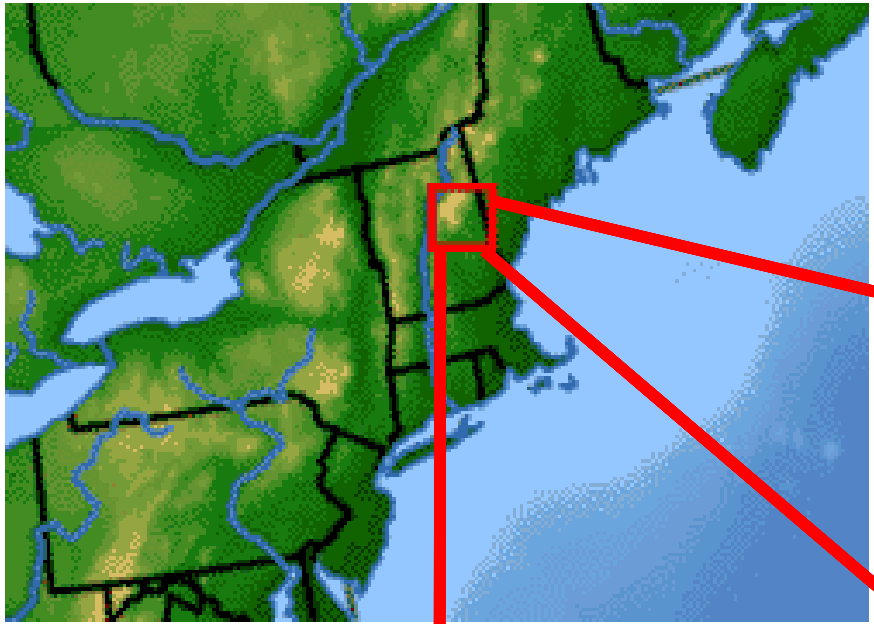
2014 2015 2016 2017



Drought

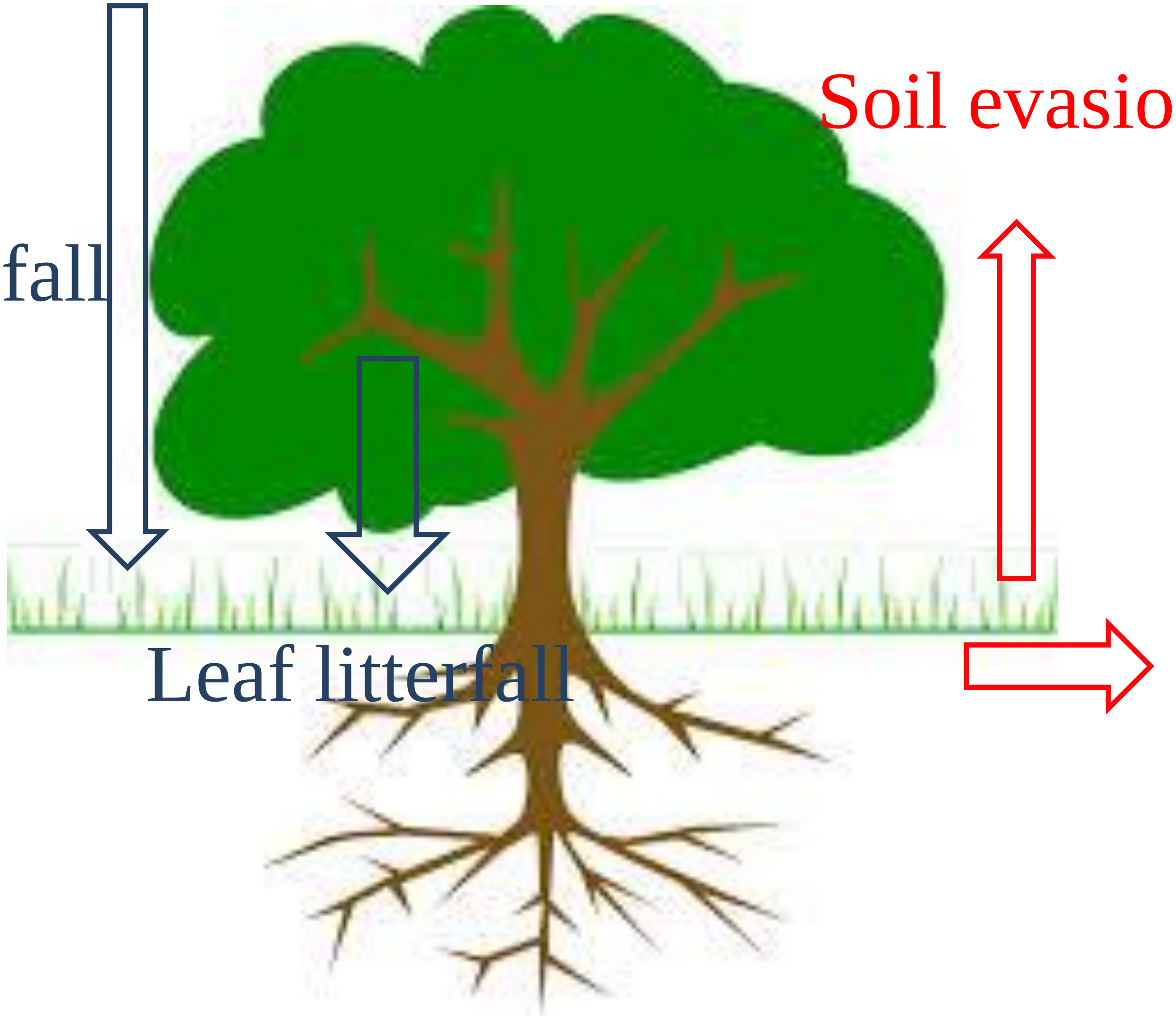
Warming

Ice storm

IR Image of Soil Warming

DroughtNet Plot

Ice Storm Experiment



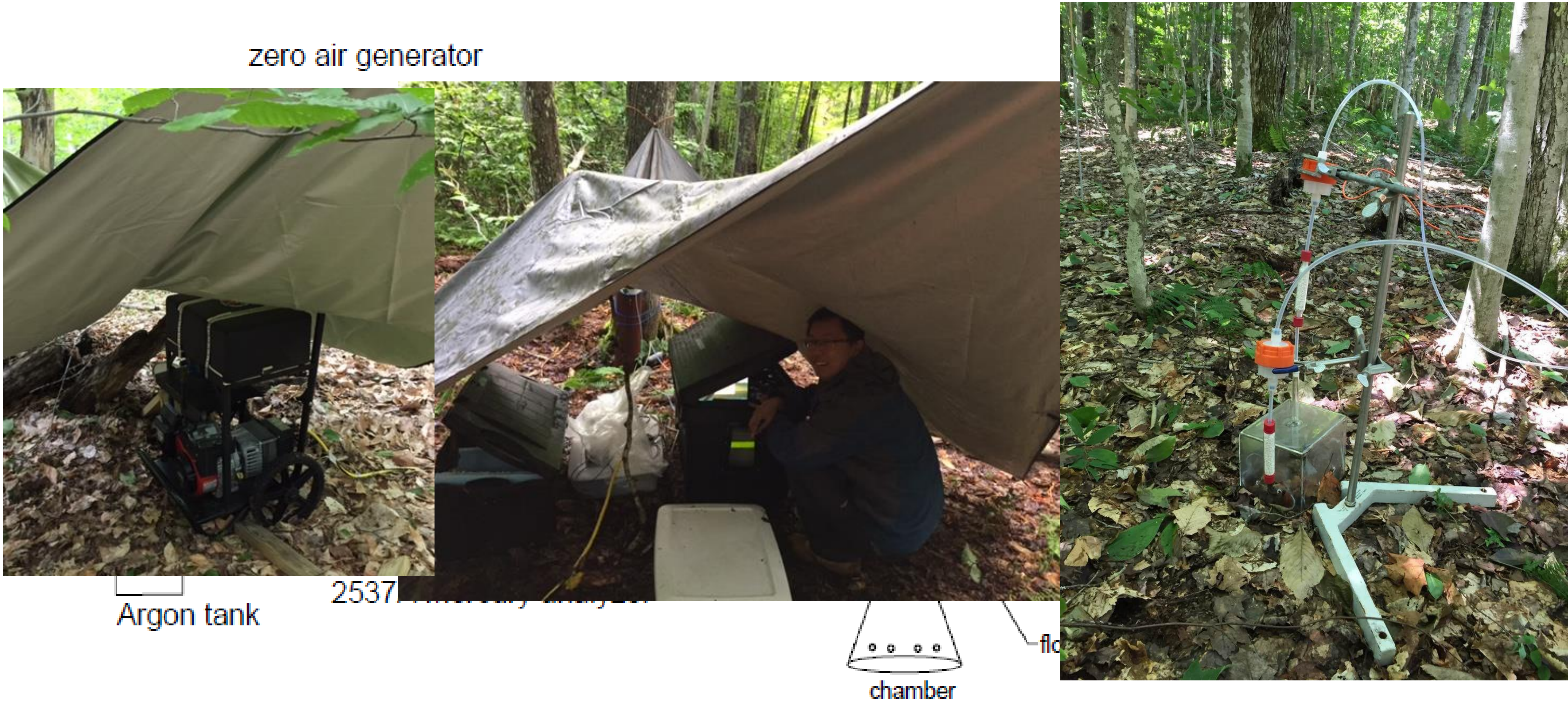
Throughfall

Soil evasion

Leaf litterfall

Soil solution

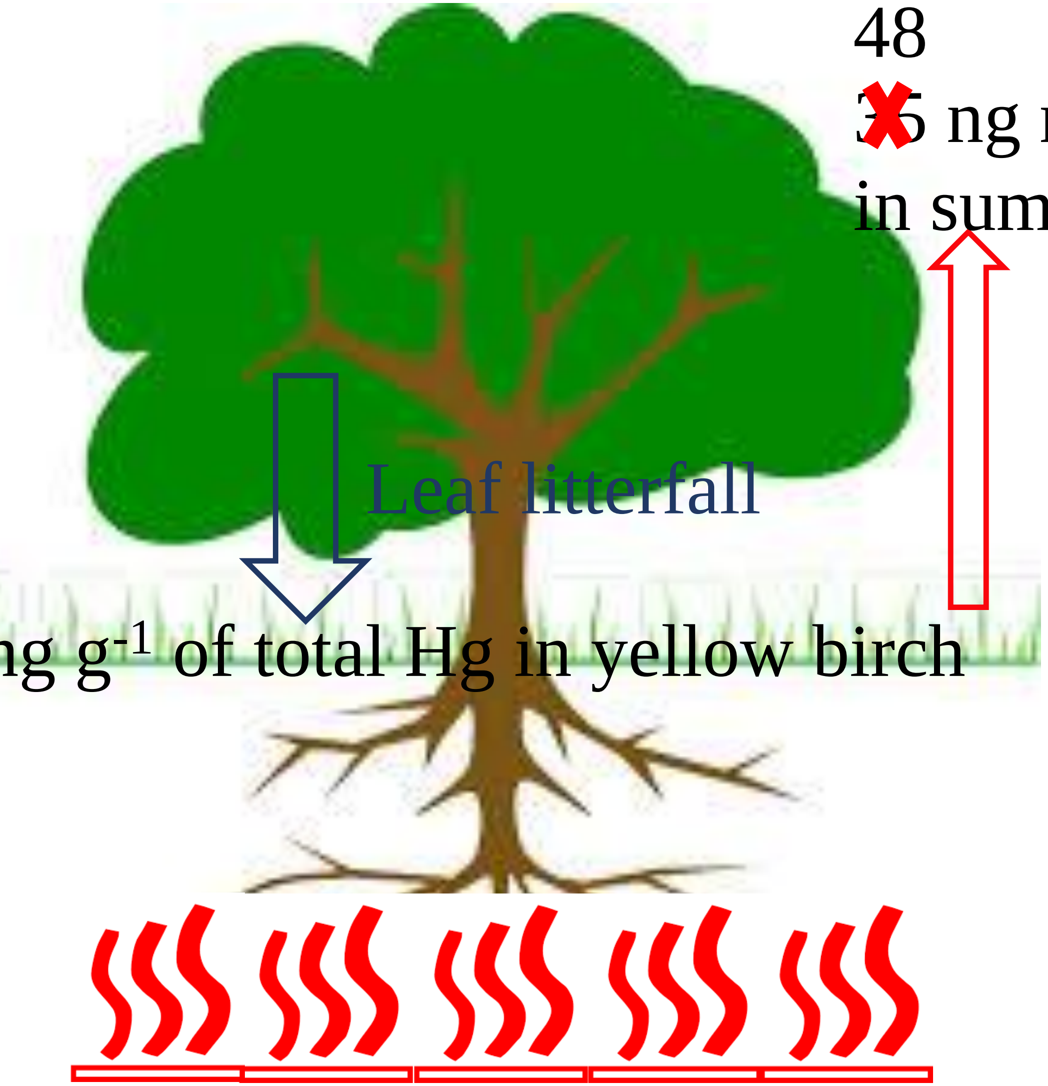
Real-time mercury flux measurement



Throughfall collection

Soil solution collection

Warming



48

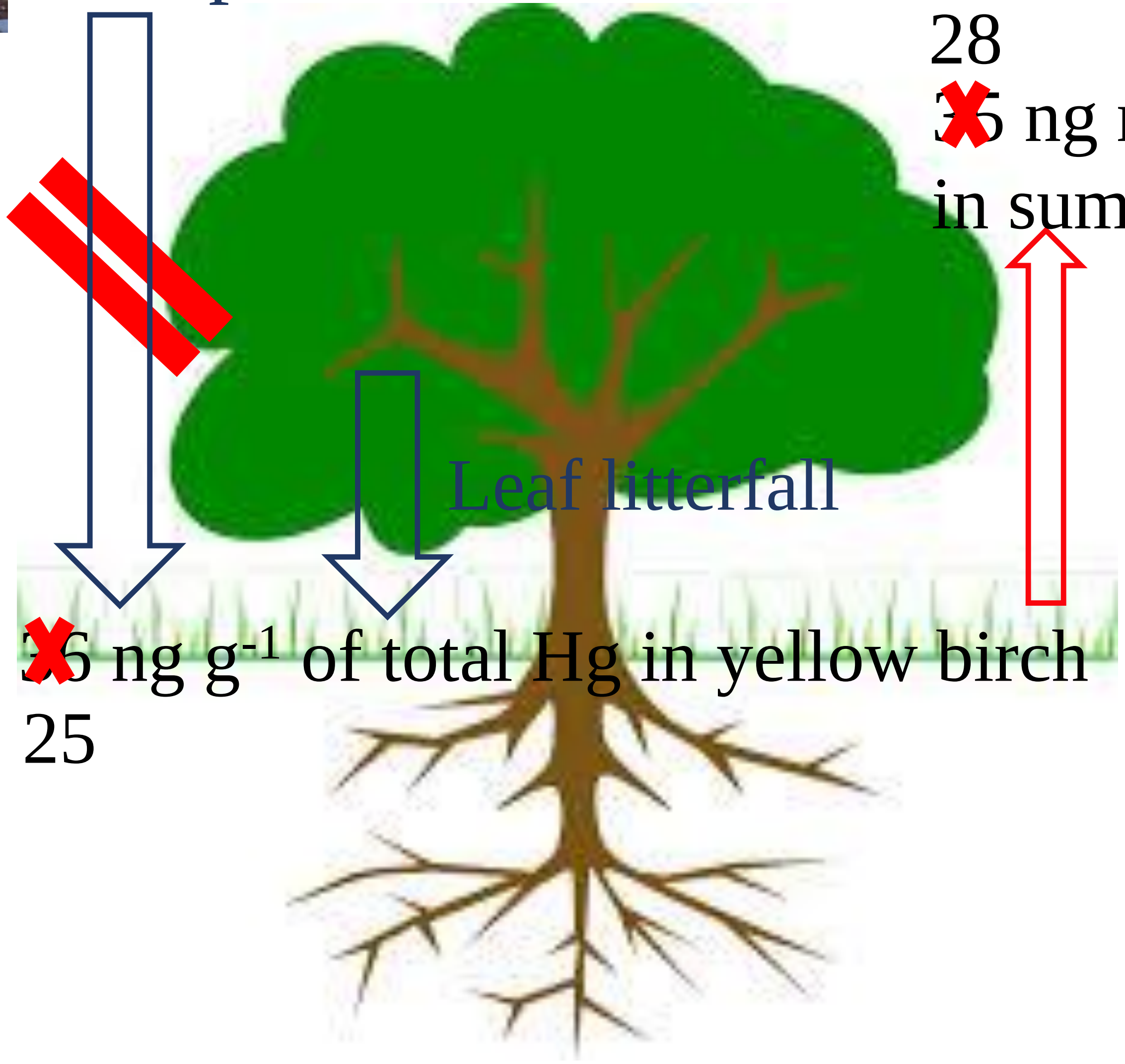
~~35~~ ng m^{-2} day^{-1} of Hg^0 emitted in summer

Leaf litterfall

40

~~36~~ ng g^{-1} of total Hg in yellow birch

Precipitation

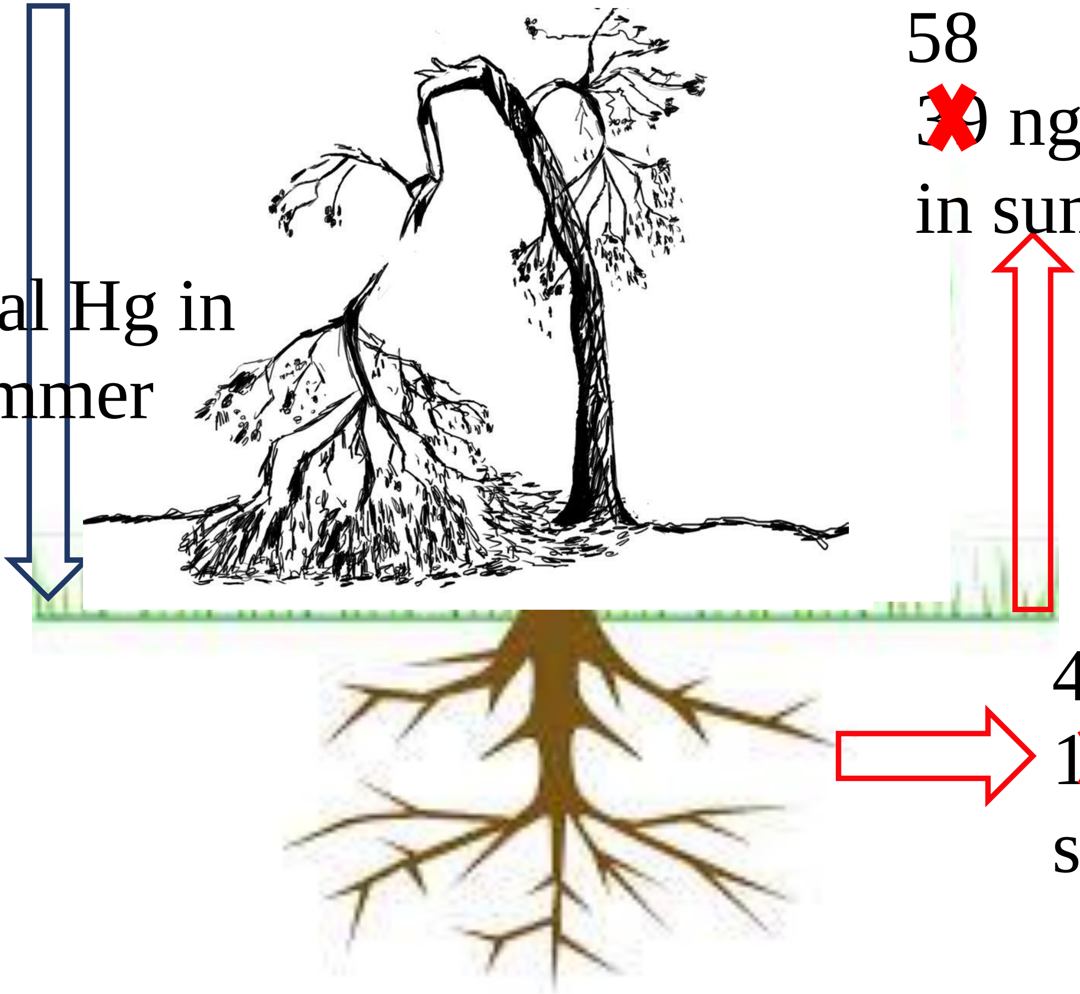


Leaf litterfall

28
~~35~~ ng m^{-2} day^{-1} of Hg^{0} emitted in summer

~~36~~ ng g^{-1} of total Hg in yellow birch
25

Ice storm



12.9

~~15.0~~ ng L^{-1} of total Hg in throughfall in summer

58

~~39~~ ng m^{-2} day^{-1} of Hg^0 emitted in summer

4.5

~~1.8~~ ng L^{-1} of total Hg in soil solutions in summer

Yang Yang, Linghui Meng, Ruth D. Yanai, Charles T. Driscoll, Mario Montesdeoca, Pamela Templer, Lindsey Rustad and Heidi Absbjornsen. Climate change may worsen mercury pollution in northern hardwood forests. IN PREPARATION

1. The warming experiment

increased inputs of Hg into forest soils from **litterfall**

increased outputs through **soil Hg evasion**

2. The simulated ice storm

decreased inputs of Hg into forest soils from **litterfall** and **throughfall**

increased outputs through **soil Hg evasion** and **leaching in soil solution**

Climate changes are likely to exacerbate Hg pollution by releasing Hg sequestered in forest soils.

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Energy. Innovation. Solutions.

2014 2015 2016 2017 2018

Sources

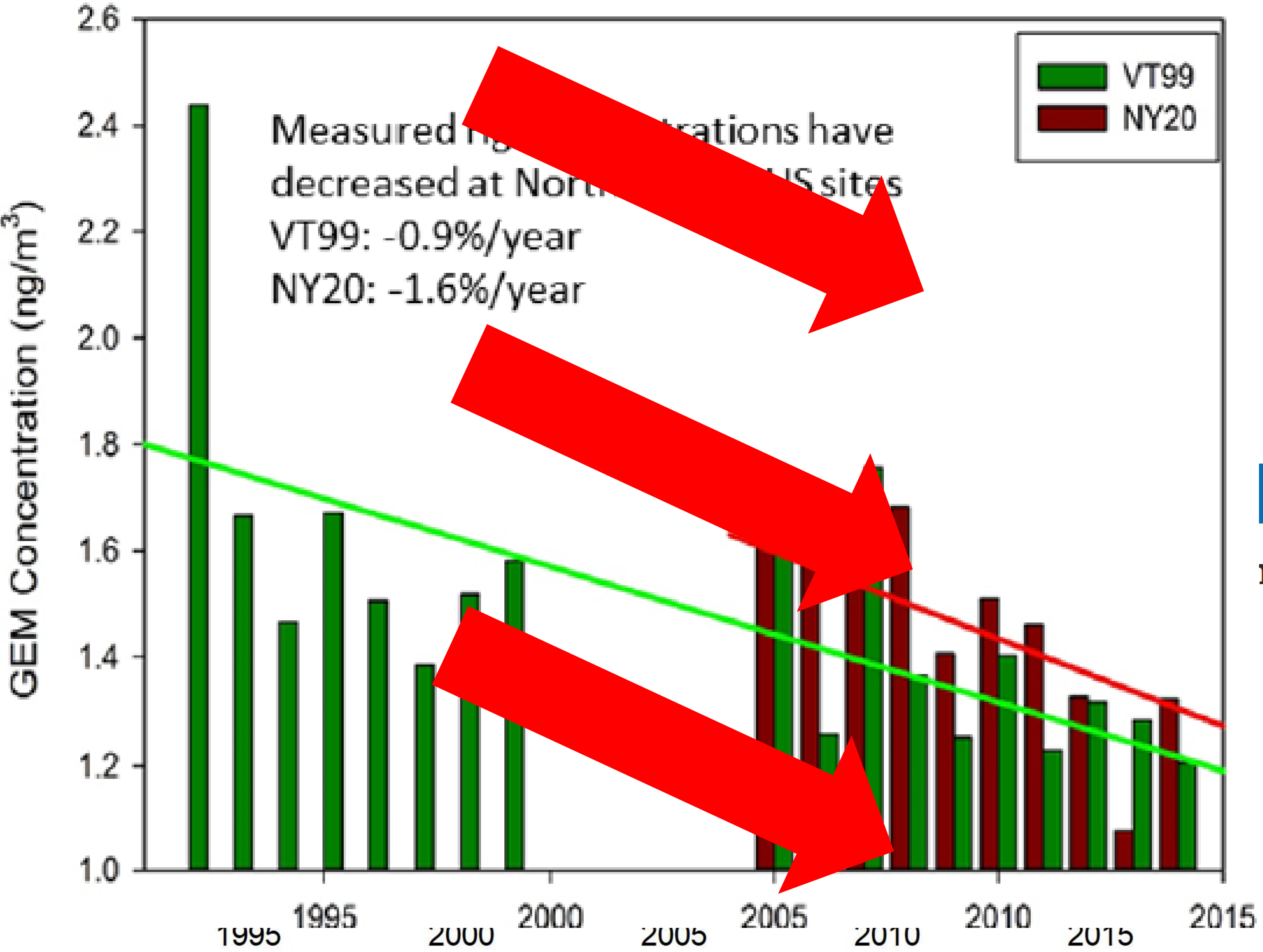
Elemental Hg
reactive gaseous Hg
particulate Hg

Wet&Dry deposition

Elemental Hg^0 ⇒ Hg^{2+} ⇒ Methyl-Hg

Clean Air Ac and mercu

- The Environm required by la study of merc



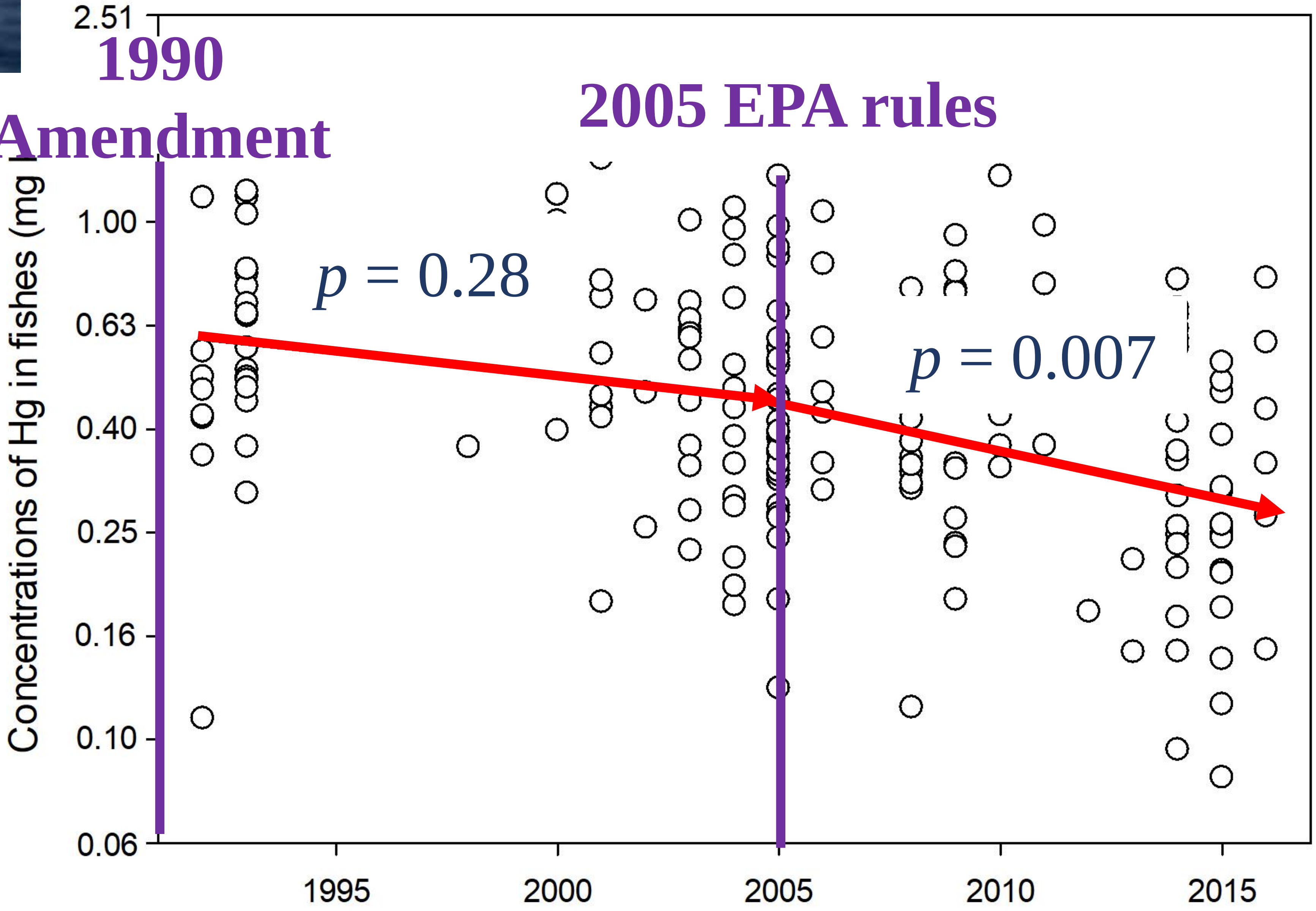
Measured rations have
decreased at Nort US sites
VT99: -0.9%/year
NY20: -1.6%/year

Zhou et al. 2016

About EPA

ıdards (MATS)

190 yellow perch from 107 lakes from 1992 to 2016



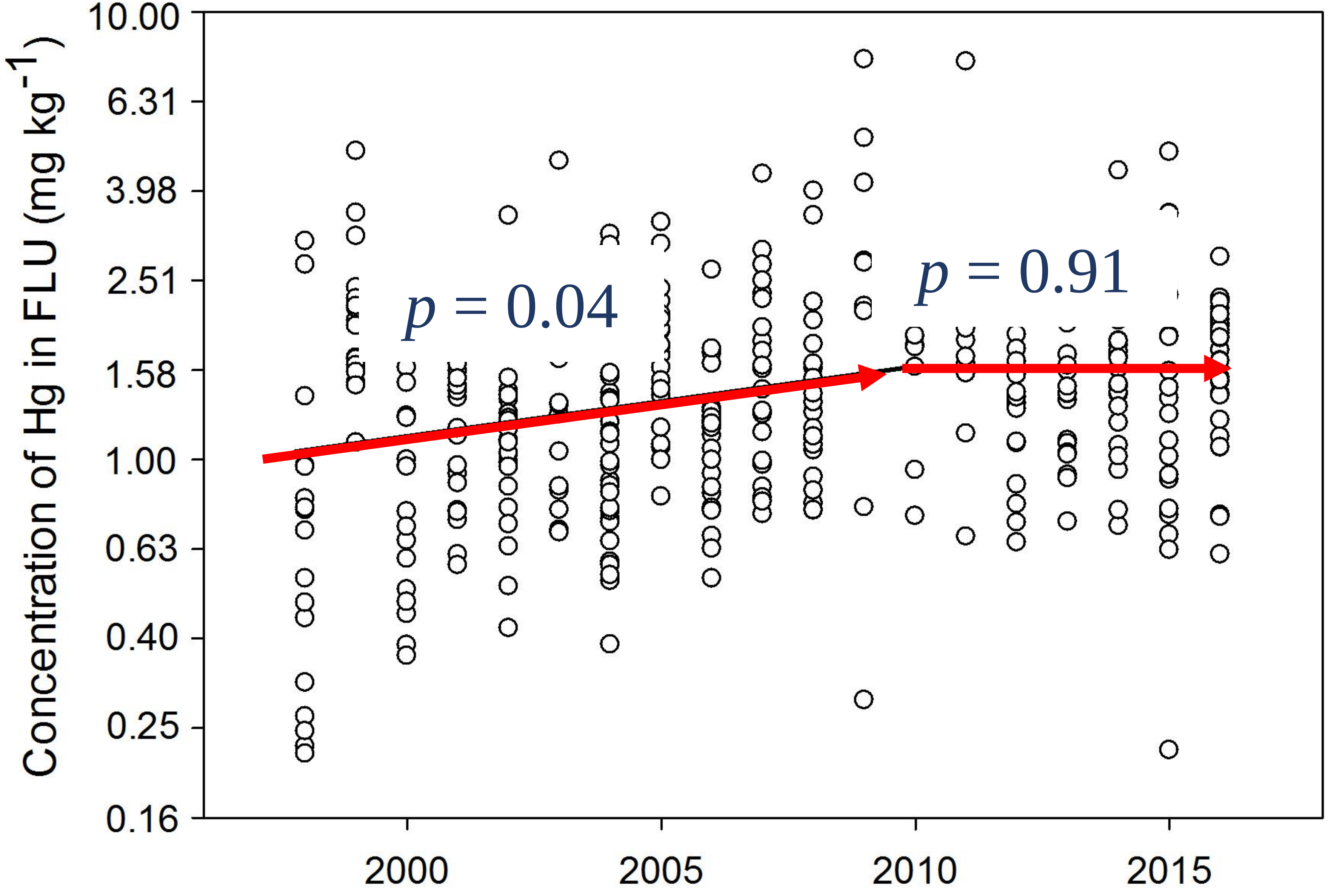
1990 Amendment

2005 EPA rules

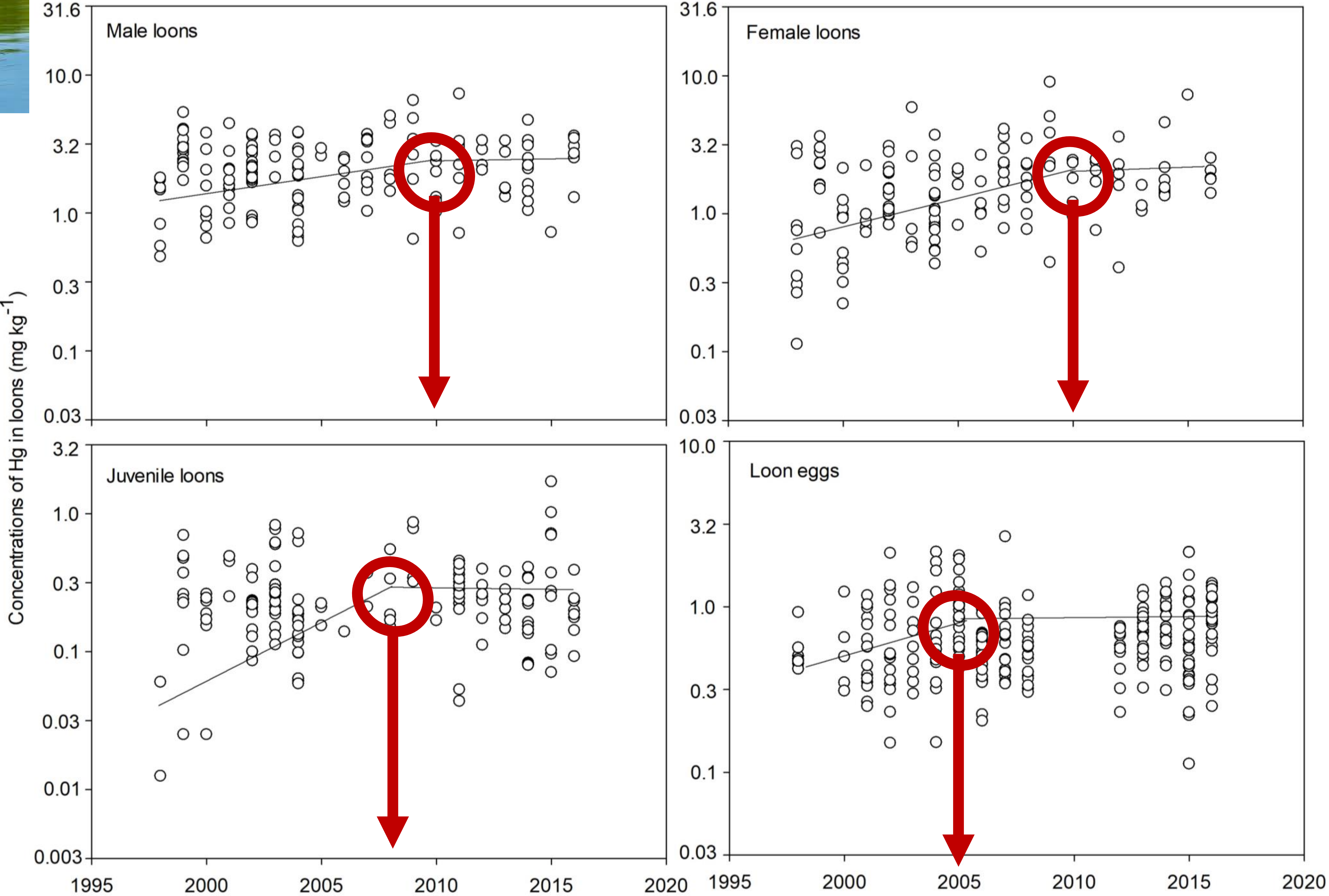
$p = 0.28$

$p = 0.007$

701 loon samples from 111 lakes from 1998 to 2016



Loon samples by gender and age from 111 lakes



Nina Schoch, Yang Yang, Ruth Yanai, David Evers and Valerie Buxton. Spatial pattern and temporal trends in mercury concentrations from 1998 to 2016 in Adirondack loons (*Gavia immer*): Has this top predator benefitted from Hg emission controls? IN PREPARATION

1. Fish have benefited from controlled Hg emission

2. Common loons have not benefited yet

3. Younger loons received benefits earlier than older loons

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Acknowledgement

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University of New Hampshire Heidi Asbjornsen, Katie Jennings

FOREST SERVICE U S DEPARTMENT OF AGRICULTURE Lindsey Rustad, Gabriel Winant

more and more…

Questions?